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(72) Inventors: ERNST, Fabian, E.; Internationaal Octrooibureau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **WILINSKI, Piotr;** Internationaal Octrooibureau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **VAN OVERVELD, Cornelius, W., A., M.;** Internationaal Octrooibureau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agent: GROENENDAAL, Antonius, W., M.; Internationaal Octrooibureau B.V., Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).
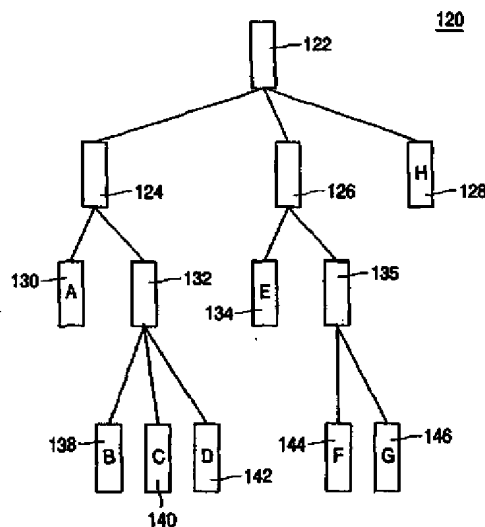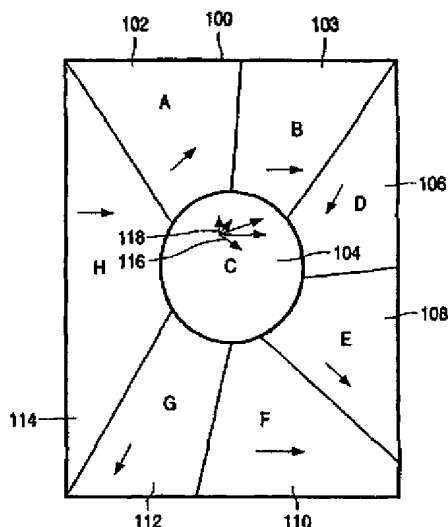
(54) Title: METHODS OF AND UNITS FOR MOTION OR DEPTH ESTIMATION AND IMAGE PROCESSING APPARATUS PROVIDED WITH SUCH MOTION ESTIMATION UNIT

(57) Abstract: In the method of motion estimation a tree (120) of segments (102-114) of an image (100) is generated by performing a hierarchical segmentation. The tree (120) of segments is analyzed to control the generation of a set (118) of candidate motion vectors of a segment (104). For the motion vectors of the set (118) match penalties are calculated. Finally, a particular motion vector (116) is selected from the set (118) of candidate motion vectors on the basis of match penalties. In the method of depth estimation depth data is calculated on the basis of a motion vector and the rules of parallax.

Methods of and units for motion or depth estimation and image processing apparatus
provided with such motion estimation unit

The invention relates to a method of motion estimation of segments of an
image, comprising the steps of:
- generating a set of candidate motion vectors of a particular segment;
- computing for each candidate motion vector a match penalty; and
5 - selecting a particular motion vector from the set of candidate motion vectors
on the basis of match penalties.

The invention further relates to a motion estimator unit for motion estimation
of segments of an image, comprising:
- a generator for generating a set of candidate motion vectors of a particular
10 segment;
- a computing means for computing for each candidate motion vector a match
penalty; and .
- a selecting means for selecting a particular motion vector from the set of
candidate motion vectors on the basis of match penalties.

15 The invention further relates to a method of depth estimation of segments of
an image, comprising the steps of:
- generating a set of candidate motion vectors of a particular segment;
- computing for each candidate motion vector a match penalty;
- selecting a particular motion vector from the set of candidate motion vectors
20 on the basis of match penalties; and
- calculating depth data of the particular segment on the basis of the particular
motion vector.

The invention further relates to a depth estimator unit for depth estimation of
segments of an image, comprising:
25 - a generator for generating a set of candidate motion vectors of a particular
segment;
- a computing means for computing for each candidate motion vector a match
penalty;

-        a selecting means for selecting a particular motion vector from the set of
candidate motion vectors on the basis of match penalties; and

-        a depth calculating means for calculating depth data of the particular segment
on the basis of the particular motion vector.

5   The invention further relates to an image processing apparatus comprising:

-        a motion estimator unit for motion estimation of segments of an image,
comprising:

        - a generator for generating a set of candidate motion vectors of the particular
segment;

10   - a computing means for computing for each candidate motion vector a match
penalty; and

        - a selecting means for selecting a particular motion vector from the set of
candidate motion vectors on the basis of match penalties; and

-        a motion compensated image processing unit.

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        A method of motion estimation of the kind described in the opening paragraph
is known from the article "True-Motion Estimation with 3-D Recursive Search Block
Matching" by G. de Haan et. al. in IEEE Transactions on circuits and systems for video
20   technology, vol.3, no.5, October 1993, pages 368-379.

        Motion estimation has been used with success in video applications for motion
compensated image processing like scan-rate up-conversion, de-interlacing and temporal
noise reduction. A category of motion estimation algorithms is called "Block matching".
Block matching algorithms are iterative minimization algorithms which assume that all pixels
25   within a given block move uniformly. For that block a match penalty is minimized with
respect to possible motion vector candidates. A match penalty might be e.g. the Sum of
Absolute differences (SAD) or Mean Squared Error (MSE). Typically, blocks are 8 by 8
pixels. However the principle of estimating motion vectors by minimization of a match
penalty works also for segments with an irregular shape. In that case, the motion
30   estimation/match penalty computation is segment based. Segment boundaries might be
aligned with luminosity or color discontinuities. In this way, segments can be interpreted as
being objects or parts of objects in the scene.

        The speed of the method of finding the best motion vectors of the various
segments of an images depends on the number of segments, the size of these segments and on

the number of possible candidate motion vectors of each segment. The accuracy depends on two factors:

-          Firstly, the size of the segments, since larger segments are less prone to noise. However the size is restricted by the fact that the motion of the segment should be constant.

5   Hence, segments should preferably coincide with the largest region still having the same motion.

-          Secondly, the choice of the candidate motion vectors. If only a limited number of candidate motion vectors is tested, a good choice of the candidate motion vectors is crucial. In the cited article the candidate set comprises the current motion vectors of

10   neighboring blocks, augmented with some random candidate motion vectors. The underlying assumption is that neighboring blocks may have a similar motion. However, neighboring blocks are only likely to have the same motion if they belong to the same object. Hence, trying candidate motion vectors which are not likely to belong to the same object is wasted computational effort. It is a disadvantage of the known method that time and computational

15   effort are wasted.

It is known that the steps of a method of motion estimation may be followed by a calculating step to obtain a method of depth estimation. The following problem is considered: given a series of images of a static scene taken by a camera with known motion, depth information should be recovered. All apparent motion in the series of images results

20   from parallax. Differences in motion between one segment and another indicate a depth difference. Indeed, analyzing two consecutive images, the parallax between a given image segment at time t and the same segment at t+1 can be computed. This parallax corresponds to the motion of different parts of the scene. In the case of translation of the camera, objects in the foreground move more than those in the background. By applying geometrical relations,

25   the depth information can be deduced from the motion. This concept is described by P. Wilinski and K. van Overveld in the article "Depth from motion using confidence based block matching" in Proceedings of Image and Multidimensional Signal Processing Workshop, pages 159-162, Alpbach, Austria, 1998.

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It is a first object of the invention to provide a method of motion estimation of the kind described in the opening paragraph with an improved performance.

It is a second object of the invention to provide a motion estimator unit of the kind described in the opening paragraph with an improved performance.

It is a third object of the invention to provide a method of depth estimation of the kind described in the opening paragraph with an improved performance.

It is a fourth object of the invention to provide a depth estimator unit of the kind described in the opening paragraph with an improved performance.

5   It is a fifth object of the invention to provide an image processing apparatus of the kind described in the opening paragraph with an improved performance.

The first object of the invention is achieved in that the method of motion estimation further comprises the steps of:

- generating a tree of the segments of the image by performing a hierarchical

10   segmentation; and

- analyzing the tree of the segments to control the generation of the set of candidate motion vectors of the particular segment.

The hierarchical segmentation provides information on the likeliness of segments belonging to the same object due to the tree structure of the segmentation. The tree has a single node at

15   the highest level, which is called the root. Each node in the tree has a unique parent at a next higher level. Each segment corresponds with a node of the tree. A parent segment has child segments. An example of a hierarchical segmentation method is known from US 5,867,605. The performance, i.e. speed and/or accuracy of the method of motion estimation can be improved with the aid of the tree in two manners: top-down and bottom-up. The advantage in

20   both cases is that the number of candidate vectors for which match penalties have to be calculated is relatively low.

In an embodiment of the method of motion estimation according to the invention, the motion vectors of the segments of the tree are estimated by processing the tree of the segments recursively in a top-down direction. This may be done according to the

25   following procedure:

- The estimation of the appropriate motion vectors starts on high level of the tree, where the segments are still large.

- If no satisfactory motion vector is found for a segment, then motion vectors are estimated for all children of this node separately.

30   - The previous step is repeated recursively until satisfactory motion vectors are obtained.

In this manner, the number of segments to be matched is minimal, without sacrificing the accuracy. The process of estimating motion vectors continues until satisfactory motion vectors are obtained. The result is that only motion vectors are estimated for segments at a

relatively high level in the tree. The advantage is that the process stops with the largest, and thus least noise-prone, segments possible.

In a modification of the embodiment of the method of motion estimation according to the invention, the motion vectors are estimated of segments, corresponding to

5   children of a node of the tree that corresponds to the particular segment, if a match penalty of the particular motion vector is unsatisfactory. The advantage of this stop criterion is its simplicity. Another criterion might be based on comparing match penalties of the motion vector of a parent segment and the motion vectors of the children segments. However applying this latter criterion implies extra computations.

10   In an embodiment of the method of motion estimation according to the invention, the motion vectors of the segments of the tree are estimated by processing the tree of the segments in a bottom-up direction. A least common ancestor of two segments is defined as the lowest node in the tree which is on the path from root to each of those segments. Segments which have a least common ancestor at a low position in the tree are

15   more likely to belong to the same object than segments which have a least common ancestor high in the tree. This information can be used to restrict the number of candidate motion vectors by taking only the relevant neighbors into account.

In an embodiment of the method of motion estimation according to the invention, the step of generating the set of candidate motion vectors of the particular segment

20   comprises the following sub-steps of:
-            generating an initial list of candidate motion vectors comprising motion vectors of neighboring segments;
-            ordering the initial list of candidate motion vectors according to positions of the corresponding nodes within the tree; and

25   -   restricting the initial list of candidate motion vectors to candidate motion vectors with a relatively high order, resulting in the set of candidate motion vectors.
The motion vectors of the neighboring segments are put in order of importance. The importance is related to the position in the tree of the least common ancestor of the particular segment and the neighboring segment under consideration. The lower the position of the least

30   common ancestor in the tree, the more important the candidate motion vector

The second object of the invention is achieved in that the motion estimator unit further comprises:
-            a segmentation means for generating a tree of the segments of the image, designed to perform a hierarchical segmentation; and

-               an analyzing means for analyzing the tree of the segments to control the generator.

Modifications of the motion estimator unit and variations thereof may correspond to modifications and variations thereof of the method described.

5   The third object of the invention is achieved in that the method of depth estimation further comprises the steps of:

-               generating a tree of the segments of the image by performing a hierarchical segmentation; and

-               analyzing the tree of the segments to control the generation of the set of

10   candidate motion vectors of the particular segment.

The fourth object of the invention is achieved in that the depth estimator unit further comprises:

-               a segmentation means for generating a tree of the segments of the image, designed to perform a hierarchical segmentation; and

15   -   an analyzing means for analyzing the tree of the segments to control the generator.

The fifth object of the invention is achieved in that the motion estimator unit of the image processing apparatus further comprises:

-               a segmentation means for generating a tree of the segments of the image,

20   designed to perform a hierarchical segmentation; and

-               an analyzing means for analyzing the tree of the segments to control the generator.

25   These and other aspects of the methods of and units for motion or depth estimation and of the image processing apparatus according to the invention will become apparent from and will be elucidated with respect to the implementations and embodiments described hereinafter and with reference to the accompanying drawings, wherein:

Figure 1 shows an image segmented into 8 segments and the corresponding

30   tree;

Figure 2A schematically shows the segments for which motion vectors are estimated in the case of a top-down approach, at the second highest level of hierarchy of the tree;

Figure 2B schematically shows the segments for which motion vectors are estimated in the case of a top-down approach, at the third highest level of hierarchy of the tree;

Figure 2C schematically shows the segments for which motion vectors are estimated in the case of a top-down approach, at the lowest level of hierarchy of the tree.

Figure 3A schematically shows elements of a motion estimator designed for a top-down approach;

Figure 3B schematically shows elements of a motion estimator unit designed for a bottom-up approach;

Figure 4 schematically shows elements of a depth estimator unit; and

Figure 5 schematically shows elements of an image processing apparatus.

Corresponding reference numerals have the same meaning in all of the Figures.

Figure 1 shows an image 100 hierarchically segmented into 8 segments 102-114 and the corresponding tree 120. The tree has 13 nodes 122-146 from which node 122 is called the root. Each node 122-146 corresponds to a segment of the image 100. For some nodes it is indicated to which segment of the image 100 it corresponds, e.g. node 130 corresponds to segment 102. References are provided for convenience, A-H.

The concept of hierarchical segmentation will be explained briefly. Hierarchical segmentation is a region-based segmentation technique in which segments in the image are determined that satisfy a certain homogeneity criterion. Subsequently, these segments are extended, e.g. grown by continuously varying the homogeneity parameter, such that the union of segments covers the whole image. Then the segmentation is complete.

The basic approach consists of the following steps:

-       A criterion for the homogeneity is chosen, e.g. the variance of the luminosity in a segment around a pixel. This means that it is decided whether or not a pixel can be considered as part of on initial segment on the basis of the luminosity variance in a region around the pixel.

-       For each value of the homogeneity criterion the resulting segments can be calculated. However preferably it is done for some pre-determined thresholds. Each threshold corresponds with a level of hierarchy in the tree.

-       A tree structure is built for the segments. Note that if for a certain value of the threshold a segment exists, this segment exists also for all higher values of the threshold. If

the threshold increases, segments can grow larger, and segments which are separated for a low value for the threshold might merge at a higher level of the threshold. However, because of the way the segments are created, it can never happen that segments decrease in size or are split if the threshold increases.

5   -   Optionally this tree is pruned to achieve separated segments.

       -            Optionally segments are grown by means of a morphological operation.

The free parameter is the threshold of the homogeneity criterion. This criterion can be specified in a very intuitive way, e.g. variance of the luminosity in a certain environment, similarity of neighboring pixels, etc.. If segments have to be merged, the tree structure

10   specifies uniquely which segments are to be merged to arrive at larger segments. Finally, the tree itself gives a structural relation between the segments.

                  The advantage of the hierarchical segmentation, resulting in the tree 120, for the estimation of the motion vector 116 of segment C 104 is described below. The method of motion estimation according to the bottom-up approach comprises the following steps:

15   -   For segment C 104 a set CS_c of candidate motion vectors V_i is generated, where V_i is the motion vector of a neighboring segment of C 104, i.e. 102,103,106-114.

       -            The candidate motion vectors are ordered according to the position of the least common ancestor in the tree 120 of node C 140 and the neighboring segment under consideration. E.g. node 132 is the least common ancestor of node C 140 and node D 142.

20   The lower the position of the least common ancestor in the tree, the more relevant the candidate motion vectors V_i.

       -            The set CS_c of candidate motion vectors is restricted to only those K motion vectors V_i which have the highest relevance.

In the situation of the prior art, the set of candidate motion vectors of segment C 104 would

25   be $CS_c = \{V_A, V_B, V_D, V_E, V_F, V_G, V_H, V_R\}$ where V_R is a random motion vector. However according to the invention it is allowed that $CS_c = \{V_B, V_D, V_A, V_R\}$ is taken, since from the tree structure it can be derived that the least common ancestor 122 of node C 140 and, e.g. node E 134 is so high up in the tree 120 that it is unlikely that segment C 104 and segment E 108 belong to the same object and have the same motion. In this case, K=3 is taken. In this

30   manner, it is possible to restrict the number of candidate motion vectors to be tested. Since the selection of the candidate motion vectors is based on the tree structure of the segmentation, only the information from the most relevant neighboring segments is used. The

result is a gain in efficiency, i.e. less candidate motion vectors to be tested without a loss in accuracy, since the non-tested candidate motion vectors are from segments which probably are part of different objects and thus less likely to have a similar motion.

Figure 2A schematically shows the segments 202,204 and 206 for which

5   motion vectors 208,210 and 212 are estimated. The tree 120 in Figure 2A shows a state in the method according to a top-down approach: the second highest level of hierarchy of the tree. The nodes 124,126 and 128 correspond with the segments for which motion vectors are estimated. The principle of the top-down approach is described in connection with Figure 3A.

Figure 2B schematically shows the segments 202,216,214,218 and 220 for

10   which motion vectors 208,222,224,226 and 228 are estimated. The tree 120 in Figure 2B shows a state in the method according to a top-down approach: the third highest level of hierarchy of the tree. The nodes 128,130,132,134 and 135 correspond with the segments for which motion vectors are estimated. By comparing Figures 2A and 2B the effect of splitting segments into smaller segments on motion vectors can be seen. E.g. a motion vector 210 was

15   estimated for segment 204 and the motion vectors 226 and 228 are estimated for the segments 214 respectively 216. E.g. a motion vector 212 was estimated for segment 206 and the motion vectors 222 and 224 are estimated for the segments 220 respectively 218.

Figure 2C schematically shows the segments 202,216,218,230,232,234 and 236 for which motion vectors 208,224,228,238,240,244 and 242 are estimated. The tree 120

20   in Figure 2C shows a state in the method according to a top-down approach: the lowest level of hierarchy of the tree. The nodes 128,130,134,138,140,142,144 and 146 correspond with the segments for which motion vectors are estimated. By comparing Figures 2B and 2C the effect of splitting segments into smaller segments on motion vectors can be seen. E.g. a motion vector 226 was estimated for the segment 214 and the motion vectors 238 and 240 are

25   estimated for the segments 230 respectively 232. A motion vector 222 was estimated for the segment 220 and the motion vectors 242 and 244 are estimated for the segments 236 respectively 234.

Figure 3A schematically shows elements of a motion estimator unit 300 designed for a top-down approach. The motion estimator unit 300 comprises:

30   -   a generator 310 for generating a set of candidate motion vectors of a particular segment;

-            a computing means 306 for computing for each candidate motion vector a match penalty;

-       a selecting means 308 for selecting a particular motion vector from the set of candidate motion vectors on the basis of match penalties;

-       a segmentation means 302 for generating a tree of the segments of the image, designed to perform a hierarchical segmentation; and

5   -   an analyzing means 304 for analyzing the tree of the segments to control the generator 310.

The input of the motion estimator unit 300 comprises images and is provided at the input connector 312. The output of the motion estimator unit 300 are motion vectors of the segments. The behavior of the motion estimator unit 300 is as follows. First a hierarchical

10   segmentation is performed by the segmentation means 302. This segmentation is performed as described in US 5,867,605. The result of the segmentation is a tree of segments. The motion vectors of the segments of the tree are estimated by processing the tree of the segments recursively in a top-down direction. This is done according to the following procedure:

15   -   The estimation of the appropriate motion vectors starts on high level of the tree, where the segments are still large.

-       If no satisfactory motion vector is found for a segment, then motion vectors are estimated for all children of this node separately. A criterion for a satisfactory motion vector is that the match penalty of the particular motion vector is less then a predetermined

20   threshold.

-       The previous step is repeated recursively until satisfactory motion vectors are obtained.

In this manner, the number of segments to be matched is minimal, without sacrificing the accuracy. The process of estimating motion vectors continues until satisfactory motion

25   vectors are obtained. The result is that only motion vectors are estimated for segments at a relatively high level in the tree. The advantage is that the process stops with the largest, and thus least noise-prone, segments possible.

Figure 3B schematically shows elements of a motion estimator unit 301 designed for a bottom-up approach. Most of the elements of this motion estimator unit 301

30   are equal to those of the motion estimator unit 300 as described in Figure 3A. The first generating means 310 for generating the set of candidate motion vectors comprises:

-       a second generating means 303 for generating an initial list of candidate motion vectors comprising motion vectors of neighboring segments;

-        an ordering means 305 for ordering the initial list of candidate motion vectors according to positions of the corresponding nodes within the tree; and

-        a filter 307 to restrict the initial list of candidate motion vectors to candidate motion vectors with a relatively high order.

5   This tree is processed in a bottom-up approach. This means that for the leaves of the tree, i.e. smallest segments, sets of candidate motion vectors are determined as described in Figure 1. When a set of motion vectors is determined for a particular segment the match penalties are calculated by the computing means 306. Then the selecting means 308 selects a particular motion vector from the set of candidate motion vectors on the basis of match penalties.

10   Figure 4 schematically shows elements of a depth estimator unit 400. The depth estimator unit 400 comprises:

-        a first generating means 310 for generating a set of candidate motion vectors of a particular segment;

-        a computing means 306 for computing for each candidate motion vector a
15   match penalty;

-        a selecting means 308 for selecting a particular motion vector from the set of candidate motion vectors on the basis of match penalties;

-        a segmentation means 302 for generating a tree of the segments of the image, designed to perform a hierarchical segmentation;

20   -   an analyzing means 304 for analyzing the tree of the segments to control the first generating means; and

-        a depth calculating means 402 for calculating depth data of the particular segment on the basis of the particular motion vector. The depth data might comprise a scalar depth value or a scalar depth value and an orientation of the object.

25   The input of the motion estimator unit 300 comprises images which are provided at the input connector 312 and camera calibration data which is provided at the input connector 416. The output of the motion estimator unit 300 are depth values for the segments. The behavior of the depth estimator unit 300 is as follows. First a hierarchical segmentation is performed by the segmentation means 302. This segmentation is performed as described in US 5,867,605.

30   The result of the segmentation is a tree of the segments that correspond with objects or parts of objects in the scene. For a particular object it is assumed that it has a depth relative to a pre-determined origin, e.g. the camera, with a value in a range of candidate values. This depth is related to motion of objects in the images. That means that if the motion of the object relative to the camera is known, then the depth can be estimated on the rules of parallax. This

implies that motion vectors have to be calculated for estimating depth. The method of depth estimation is according to the method described in the article "Depth from motion using confidence based block matching" in Proceedings of Image and Multidimensional Signal Processing Workshop, pages 159-162, Alpbach, Austria, 1998. In Figure 4 it is depicted that

5   the selecting means 308 provides the particular motion vector of a segment to the depth calculating means 402. The motion estimation can be as described in Figure 3A or as described in Figure 3B.

Figure 5 schematically shows elements of an image processing apparatus 500 comprising:

10   -   receiving means 501 for receiving a signal representing images to be displayed after some processing has been performed. The signal may be a broadcast signal received via an antenna or cable but may also be a signal from a storage device like a VCR (Video Cassette Recorder) or Digital Versatile Disk (DVD). The signal is provided at the input connector 506.

15   -   a motion estimator unit 300 or 301 as described in connection with Figure 3A respectively Figure 3B;

         -            a motion compensated image processing unit 502; and

         -            a display device for displaying the processed images.

The motion compensated image processing unit 502 supports the following types of

20   processing:

         -            De-interlacing: Interlacing is the common video broadcast procedure for transmitting the odd or even numbered image lines alternately. De-interlacing attempts to restore the full vertical resolution, i.e. make odd and even lines available simultaneously for each image;

25   -   Up-conversion: From a series of original input images a larger series of output images is calculated. Output images are temporally located between two original input images; and

         -            Temporal noise reduction.

The motion compensated image processing unit 502 requires images and motion vectors as

30   its input. In case of a 3D display device, e.g. with a lenticular screen, the depth values can be used to render 3D images.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention and that those skilled in the art will be able to design alternative embodiments without departing from the scope of the appended claims. In the claims, any

reference signs placed between parentheses shall not be constructed as limiting the claim. The word 'comprising' does not exclude the presence of elements or steps not listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention can be implemented by means of hardware

5   comprising several distinct elements and by means of a suitably programmed computer. In the unit claims enumerating several means, several of these means can be embodied by one and the same item of hardware.

CLAIMS:

1.   A method of motion estimation of segments (102-114) of an image (100),
comprising the steps of:
-          generating a set (118) of candidate motion vectors of a particular segment
(104);
5   -   computing for each candidate motion vector a match penalty; and
-          selecting a particular motion vector (116) from the set (118) of candidate
motion vectors on the basis of match penalties,
characterized in further comprising the steps of:
-          generating a tree (120) of the segments (102-114) of the image (100) by
10   performing a hierarchical segmentation; and
-          analyzing the tree (120) of the segments (102-114) to control the generation of
the set (118) of candidate motion vectors of the particular segment (104).

2.   A method of motion estimation as claimed in Claim 1, characterized in that
15   motion vectors of the segments (102-114) of the tree (120) are estimated by processing the
tree (120) of the segments (102-114) recursively in a top-down direction.

3.   A method of motion estimation as claimed in Claim 2, characterized in that
motion vectors are estimated of segments (102-114), corresponding to children of a node of
20   the tree (120) that corresponds to the particular segment (104), if a match penalty of the
particular motion vector (116) is unsatisfactory.

4.   A method of motion estimation as claimed in Claim 1, characterized in that the
motion vectors of the segments (102-114) of the tree (120) are estimated by processing the
25   tree (120) of the segments (102-114) in a bottom-up direction.

5.   A method of motion estimation as claimed in Claim 4, characterized in that the
step of generating the set (118) of candidate motion vectors of the particular segment (104)
comprises the following sub-steps of:

-       generating an initial list of candidate motion vectors comprising motion
vectors of neighboring segments (102-114);

-       ordering the initial list of candidate motion vectors according to positions of
the corresponding nodes (122-146) within the tree (120); and

5   -   restricting the initial list of candidate motion vectors to candidate motion
vectors with a relatively high order, resulting in the set (118) of candidate motion vectors.

6.   A motion estimator unit (300,301) for motion estimation of segments (102-
114) of an image, comprising:

10   -   a first generating means (310) for generating a set (118) of candidate motion
vectors of a particular segment (104);

-       a computing means (306) for computing for each candidate motion vector a
match penalty; and

-       a selecting means (308) for selecting a particular motion vector (116) from the
15   set (118) of candidate motion vectors on the basis of match penalties,
characterized in further comprising:

-       a segmentation means (302) for generating a tree (120) of the segments (102-
114) of the image, designed to perform a hierarchical segmentation; and

-       an analyzing means (304) for analyzing the tree (120) of the segments (102-
20   114) to control the first generating means (310).

7.   A motion estimator unit (300) as claimed in Claim 6, characterized in being
designed to estimate motion vectors of the segments (102-114) of the tree (120) by
processing the tree (120) of the segments (102-114) recursively in a top-down direction.

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8.   A motion estimator unit (300) as claimed in Claim 7, characterized in being
designed to estimate motion vectors of segments (102-114), corresponding to children of a
node of the tree (120) that corresponds to the particular segment (104), if a match penalty of
the particular motion vector (116) is unsatisfactory.

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9.   A motion estimator unit (301) as claimed in Claim 6, characterized in being
designed to estimate motion vectors of the segments (102-114) of the tree (120) by
processing the tree (120) of the segments (102-114) in a bottom-up direction.

10.   A motion estimator unit (301) as claimed in Claim 9, characterized in that the

first generating means (310) for generating the set (118) of candidate motion vectors of the

particular segment (104) comprises:

-         a second generating means (303) for generating an initial list of candidate

5   motion vectors comprising motion vectors of neighboring segments (102-114);

-         an ordering means (305) for ordering the initial list of candidate motion

vectors according to positions of the corresponding nodes (122-146) within the tree (120);

and

-         a filter (307) to restrict the initial list of candidate motion vectors to candidate

10   motion vectors with a relatively high order.

11.   A method of depth estimation of segments (102-114) of an image, comprising

the steps of:

-         generating a set (118) of candidate motion vectors of a particular segment

15   (104);

-         computing for each candidate motion vector a match penalty;

-         selecting a particular motion vector (116) from the set (118) of candidate

motion vectors on the basis of match penalties; and

-         calculating depth data of the particular segment (104) on the basis of the

20   particular motion vector (116),

characterized in further comprising the steps of:

-         generating a tree (120) of the segments (102-114) of the image (100) by

performing a hierarchical segmentation; and

-         analyzing the tree (120) of the segments (102-114) to control the generation of

25   the set (118) of candidate motion vectors of the particular segment (104).

12.   A depth estimator unit (400) for depth estimation of segments (102-114) of an

image, comprising:

-         a first generating means (310) for generating a set (118) of candidate motion

30   vectors of a particular segment (104);

-         a computing means (306) for computing for each candidate motion vector a

match penalty;

-         a selecting means (308) for selecting a particular motion vector (116) from the

set (118) of candidate motion vectors on the basis of match penalties; and

-              a depth calculating means (402) for calculating depth data of the particular segment (104) on the basis of the particular motion vector (116),

characterized in further comprising:

-              a segmentation means (302) for generating a tree (120) of the segments (102-

5   114) for the image (100) by performing a hierarchical segmentation; and

-              an analyzing means (304) for analyzing the tree (120) of the segments (102-

114) to control the first generating means.

13.   An image processing apparatus (500) comprising:

10   -   a motion estimator unit (300,301) for motion estimation of segments (102-

114) of an image (100), comprising:

               - a generator (310) for generating a set (118) of candidate motion vectors of a

particular segment (104);

               - a computing means (306) for computing for each candidate motion vector a

15   match penalty; and

               - a selecting means (308) for selecting a particular motion vector (116) from

the set (118) of candidate motion vectors on the basis of match penalties; and

-              a motion compensated image processing unit (502),

characterized in that the motion estimator unit (300,301) comprises:

20   -   a segmentation means (302) for generating a tree (120) of the segments (102-

114) of the image (100), designed to perform a hierarchical segmentation method; and

-              an analyzing means (304) for analyzing the tree (120) of the segments (102-
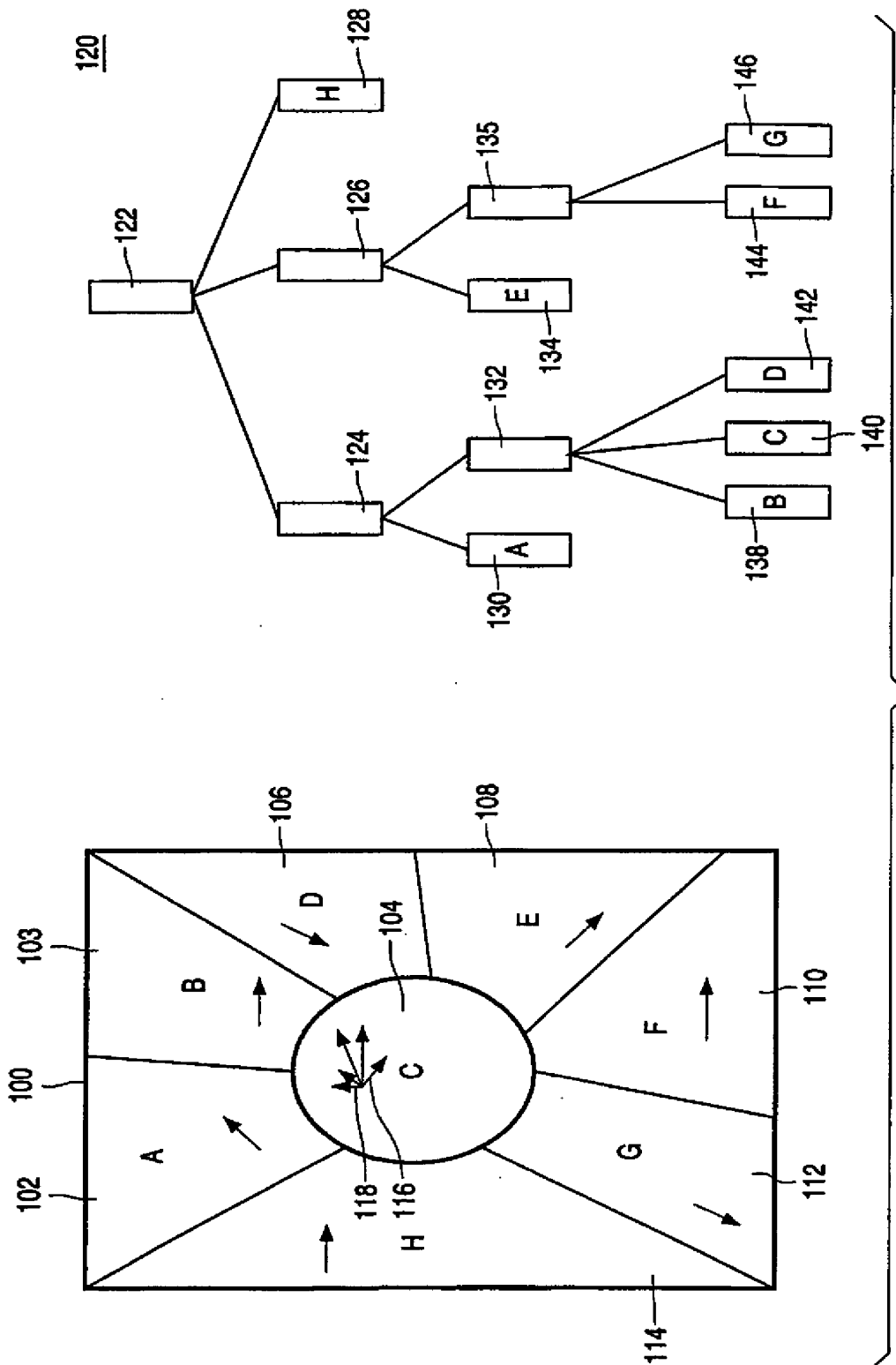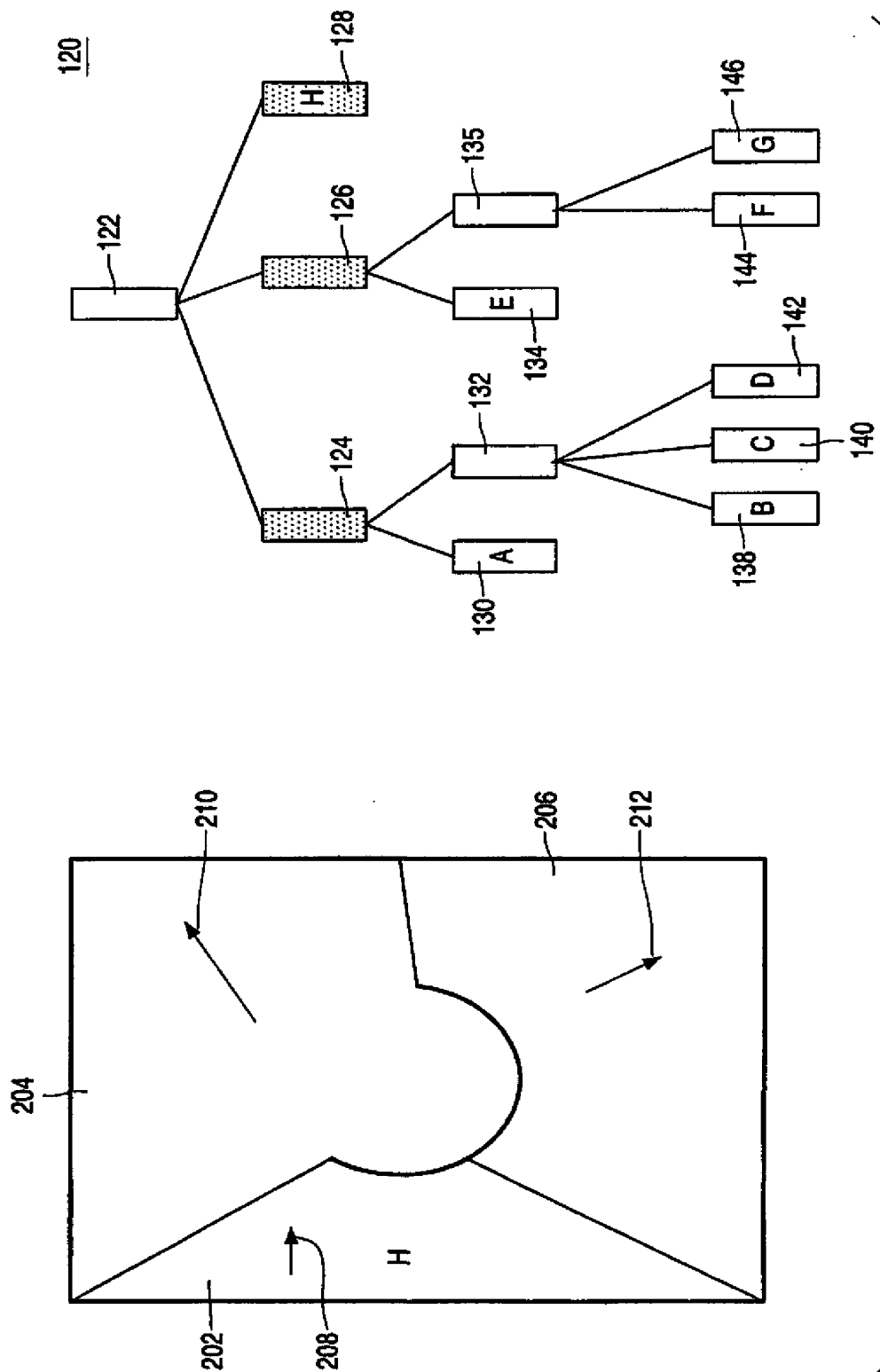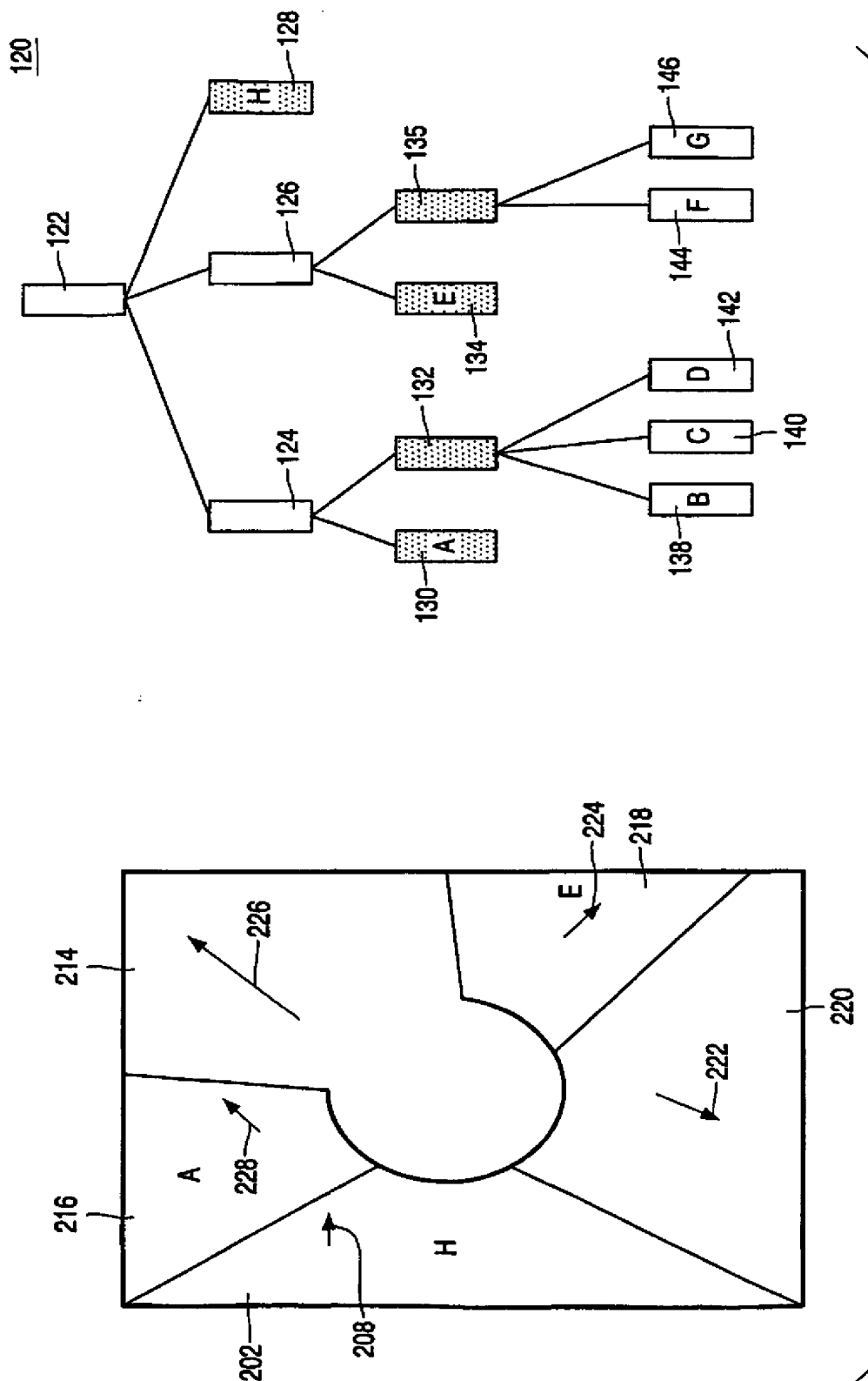
114) to control the generator (310).

FIG. 1

120

122

124 126

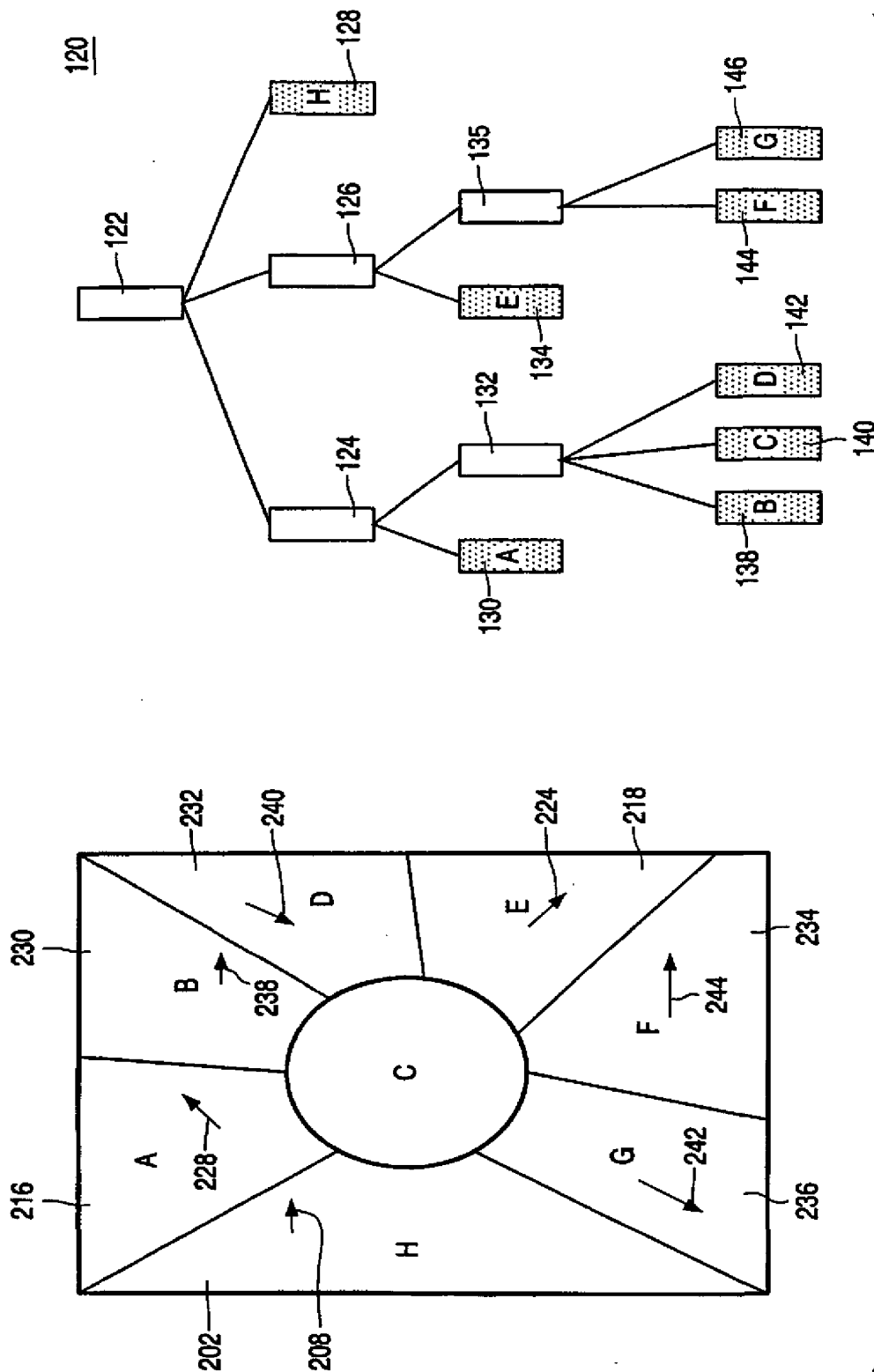130 A 132 134 E 135 128 H

138 B 140 C 142 D 144 F 146 G

204

210
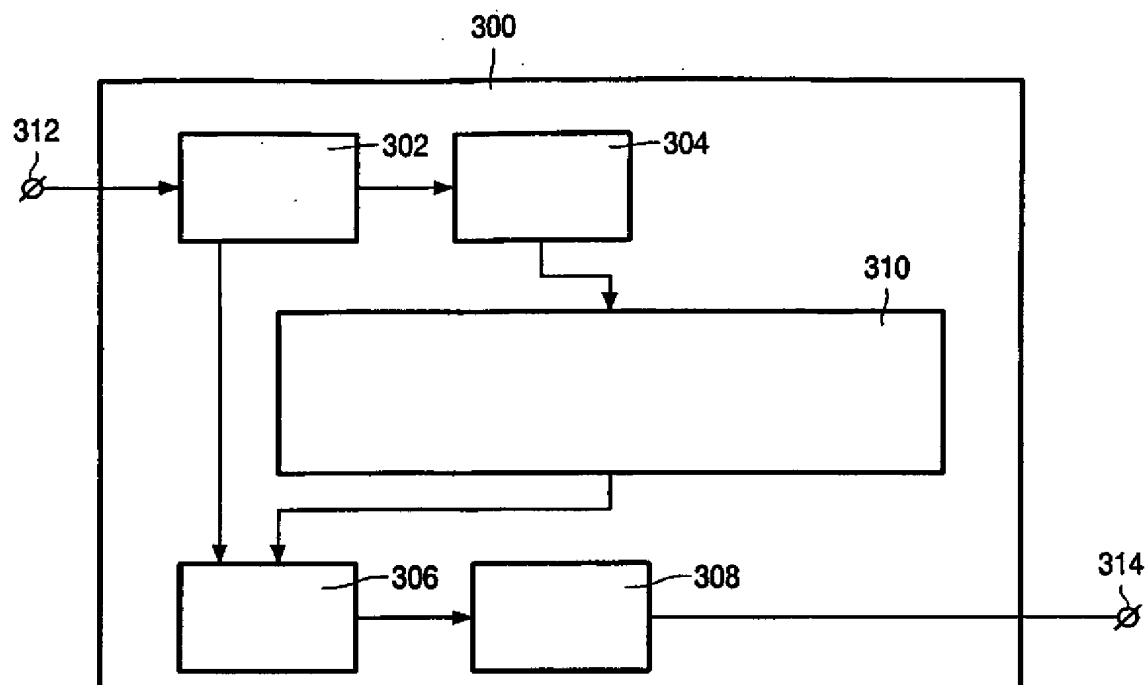
202

208 H

206

212

FIG. 2A

FIG. 2B

FIG. 2C

FIG. 3A
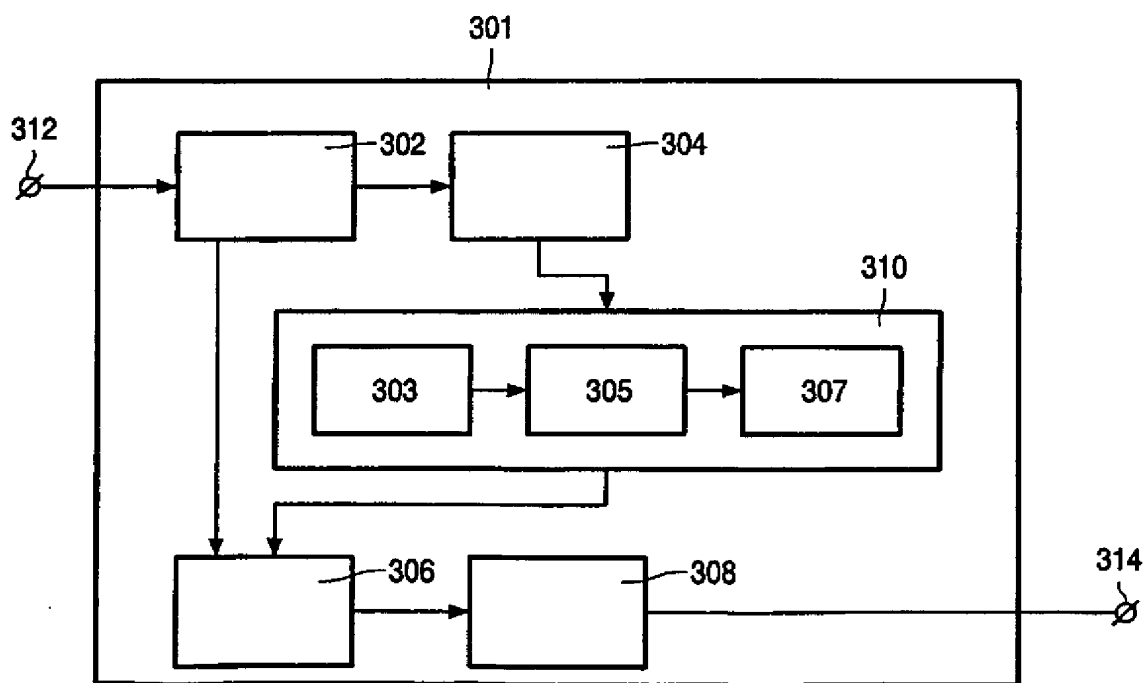
FIG. 3B

6/6
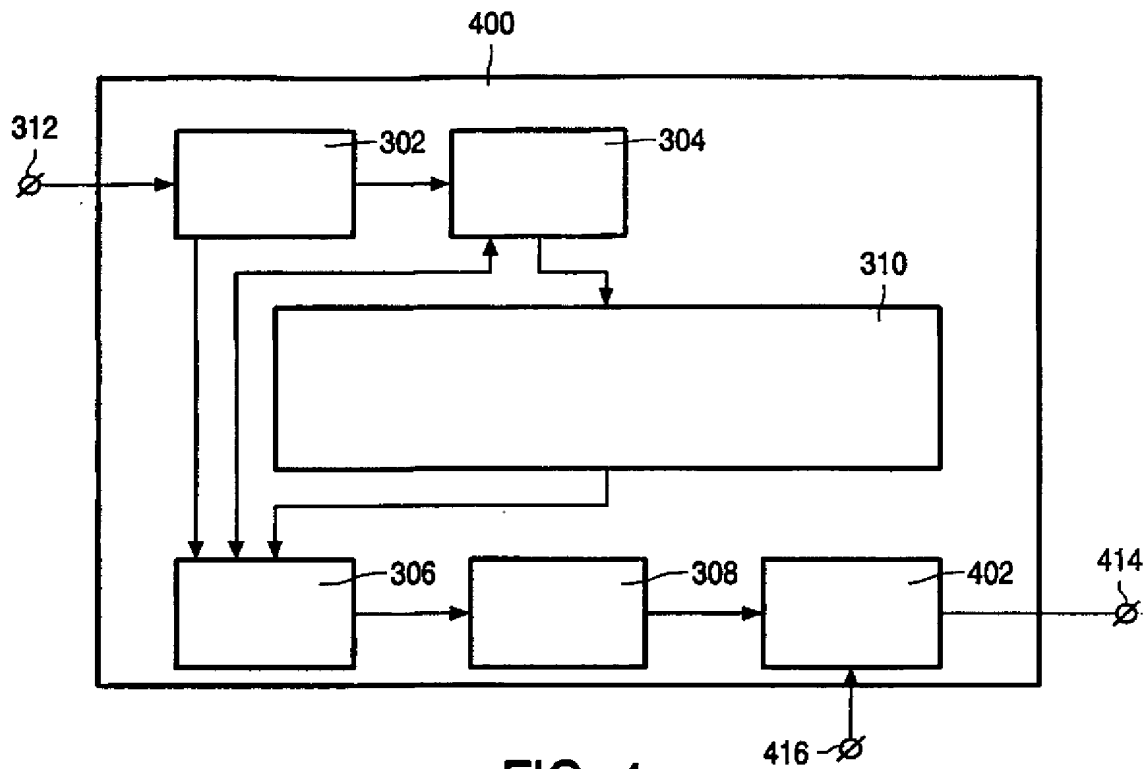
FIG. 4
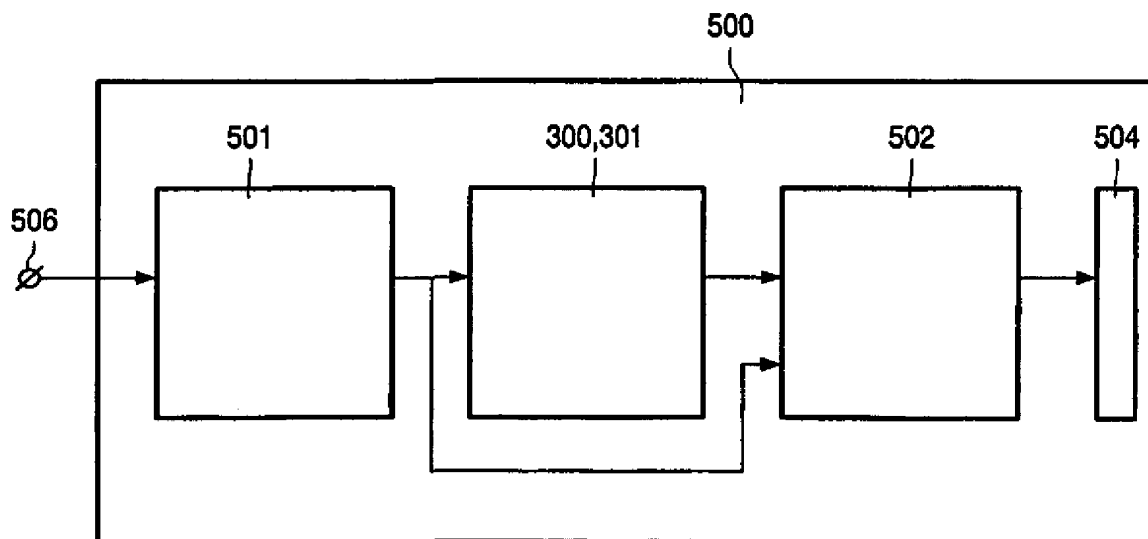
FIG. 5

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04N7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DUFAUX F ET AL: "MOTION ESTIMATION TECHNIQUES FOR DIGITAL TV: A REVIEW AND A NEW CONTRIBUTION" PROCEEDINGS OF THE IEEE, IEEE. NEW YORK, US, vol. 83, no. 6, June 1995 (1995-06), pages 858-875, XP000518740 ISSN: 0018-9219 section IV.B. - IV.D. --- -/--	1-10,13
Y		11,12

[X] Further documents are listed in the continuation of box C.   [ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
22 October 2002	29/10/2002

Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Fassnacht, C

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	SUNE J-L ET AL: "DEPTH-FROM-MOTION ESTIMATION BASED ON A MULTISCALE ANALYSIS OF MOTION CONSTRAINT EQUATION VALIDITY" PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON IMAGE PROCESSING. (ICIP). WASHINGTON, OCT. 23 - 26, 1995, LOS ALAMITOS, IEEE COMP. SOC. PRESS, US, vol. 1, 23 October 1995 (1995-10-23), pages 402-405, XP000624260 ISBN: 0-7803-3122-2 the whole document ---	11,12
X	SCHUTTEN R J ET AL: "Layered motion estimation" PHILIPS JOURNAL OF RESEARCH, ELSEVIER, AMSTERDAM, NL, vol. 51, no. 2, 1998, pages 253-267, XP004126962 ISSN: 0165-5817 sections 2.-3.3.	1-10,13
A	---	11,12
A	CHAN E ET AL: "Review of block matching based motion estimation algorithms for video compression" ELECTRICAL AND COMPUTER ENGINEERING, 1993. CANADIAN CONFERENCE ON VANCOUVER, BC, CANADA 14-17 SEPT. 1993, NEW YORK, NY, USA,IEEE, 14 September 1993 (1993-09-14), pages 151-154, XP010117942 ISBN: 0-7803-1443-3 section 3.3. ---	1,5,6,10
A	SAITO T ET AL: "Global motion segmentation for mid-level representation of moving images" PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON IMAGE PROCESSING. (ICIP). WASHINGTON, OCT. 23 - 26, 1995, LOS ALAMITOS, IEEE COMP. SOC. PRESS, US, vol. 3, 23 October 1995 (1995-10-23), pages 402-405, XP010197110 ISBN: 0-7803-3122-2 sections 2.1., 4.1. ---	1-4,6-9, 11-13

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INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	ACCAME M ET AL: "HIERARCHICAL MOTION ESTIMATOR (HME) FOR BLOCK-BASED VIDEO CODERS" IEEE TRANSACTIONS ON CONSUMER ELECTRONICS, IEEE INC. NEW YORK, US, vol. 43, no. 4, 1 November 1997 (1997-11-01), pages 1320-1329, XP000768589 ISSN: 0098-3063 the whole document ---	1-13
A	HAAN DE G ET AL: "TRUE-MOTION ESTIMATION WITH 3-D RECURSIVE SEARCH BLOCK MATCHING" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE INC. NEW YORK, US, vol. 3, no. 5, 1 October 1993 (1993-10-01), pages 368-379, XP000414663 ISSN: 1051-8215 cited in the application the whole document -----	1-13